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Applying the AcciMap methodology to investigate the tragic Sewol Ferry accident in South Korea

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A B S T R A C T

This study applies the AcciMap methodology, which was originally proposed by Professor Jens Rasmussen (1997), to the analysis of the tragic Sewol Ferry accident in South Korea on April 16, 2014, which killed 304 mostly young people and is considered as a national disaster in that country. This graphical representation, by incorporating associated socio-technical factors into an integrated framework, provides a big-picture to illustrate the context in which an accident occurred as well as the interactions between different levels of the studied system that resulted in that event. In general, analysis of past accidents within the stated framework can define the patterns of hazards within an industrial sector. Such analysis can lead to the definition of preconditions for safe operations, which is a main focus of proactive risk management systems.

In the case of the Sewol Ferry accident, a lot of the blame has been placed on the Sewol's captain and its crewmembers. However, according to this study, which relied on analyzing all available sources published in English and Korean, the disaster is the result of a series of lapses and disregards for safety across different levels of government and regulatory bodies, Chonghaejin Company, and the Sewol's crewmembers. The primary layers of the AcciMap framework, which include the political environment and non-proactive governmental body; inadequate regulations and their lax oversight and enforcement; poor safety culture; inconsideration of human factors issues; and lack of and/or outdated standard operating and emergency procedures were not only limited to the maritime industry in South Korea, and the Sewol Ferry accident, but they could also subject any safety-sensitive industry anywhere in the world.

1. Introduction

Accidents in complex socio-technical systems are the result of a loss of control over hazardous work processes, which can cause injuries to people, loss of investment, or damage to the environment (Rasmussen, 1997; Rasmussen et al., 1994).

Over the years, a large number of accident investigation methodologies have been developed to analyze a wide range of domains and capture the increasing complexity of those domains. In this paper, the main focus is on the analysis of safety-critical systems. These systems are typified by several main characteristics. First, the technology they use changes very rapidly at the operative level (Rasmussen and Svedung, 2000). Second, they have complex interactions resulting from unfamiliar or unexpected sequences of events that are often either imperceptible or not immediately comprehensible (Wang, 2008). Third, the propagation of an accidental course of events in these systems “is shaped by the activity of people which either can trigger an accidental flow of events or divert a normal flow. Safety, then, depends on the control of work processes so as to avoid accidental side effects causing harm to people, environment, or investment” (Rasmussen, 1997, p.184).

The investigation of major accidents in safety-critical systems reveals a variety of contributing factors, both from within involved organizations and from dysfunctional interactions between them in a broader perspective. Based on this analysis, accidents do not occur as the act of an isolated individual or a front-line operator, but due to highly interactive and collective processes as well as the influence of involved decision-makers in all relevant levels of society (Le

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Coze, 2015; Trotter et al., 2013, 2014). As a result, there is a need for accident investigation frameworks that integrate the analysis of contributing factors from different parts of a socio-technical system with interactions between them.

There have been several developed methodologies to better understand and analyze accidents. Some examples of these methodologies include the systems-theoretic accident model and processes (STAMP) by Leveson (2004, 2011), Reason's model of organizational accidents (1997) and Rasmussen's AcciMap approach (1997). Rasmussen's AcciMap approach is particularly useful for this purpose as it models different contributing factors of an accident, and their interactions, in a causal diagram.

One example of catastrophic events in safety-critical systems is the Sewol Ferry accident. On April 16, 2014, Sewol Ferry, the South Korean ship carrying 476 passengers from Inchon to Jeju Island, sank disastrously. The 18-year-old Japanese-built ship was purchased by a company named Chonghaejin, which added two more floors to the ship to hold more passengers, making the ship extremely unstable (해양안전심판원 특별조사부, 2014). During the voyage, when the ship made a sharp turn, it lost its balance and started to list. When the captain Jun Seok Lee communicated with the Vessel Traffic Service (VTS) for help, the captain made questionable decisions such as telling the VTS that the passengers could not evacuate and instructing the passengers to stay on-board (해양안전심판원 특별조사부, 2014). By the time the captain finally told everyone to evacuate, it was too late. At that time, he uncustomary had already left the Ferry. As the result of this accident, 304 people, who were mostly high school students, lost their lives in what is considered to be one of the most tragic maritime accidents in the history of South Korea.

This paper applies the AcciMap methodology for the analysis of the Sewol Ferry accident by investigating different contributing causes of that accident as well as the interactions between them. It is noteworthy that although the AcciMap framework has been utilized to analyze the contributing causes of the Sewol Ferry accident, this is just a case study in this paper in order to highlight the importance and vast applications of this powerful methodology for the analysis of past accidents and the generalization of lessons learned in order to prevent future system failures and catastrophes. The analysis of past accidents within the stated framework can define the patterns of hazards within an industrial sector, which can lead to definition of preconditions for safe operations, as a main focus of proactive risk management systems.

The investigation of this research is based on some main stream media, the Korea Maritime Safety Tribunal Investigation Report as well as our personal communication with scholars and professors in Korea Advanced Institute of Science and Technology (KAIST) of higher educations and Korea Industrial Safety Corporation.

In the scope of this paper, we have followed the spirit of the AcciMap methodology to identify the contributing causes and the involved decision-makers of the Sewol Ferry accident. However, we do not intend to put blame on any entity.

Based on this introduction, the outline of this paper is as follows: Section 2 introduces the Rasmussen's risk management framework as well as the AcciMap methodology. Section 3 describes in detail our developed AcciMap framework for the analysis of the Sewol Ferry accident. In Section 4, we further discuss the results of analyzing our developed AcciMap framework. Finally, we go through some concluding points in Section 5.

2. Rasmussen's risk management framework and AcciMap methodology

Rasmussen introduces a 6-layer, hierarchical framework (Fig. 1), known as risk management framework, with each level representing a main group of involved decision-makers, players or stakeholders in a studied system (Rasmussen, 1997). These six levels, from top to bottom, are: government, regulators and associations, company, management, staff, and work. Analysis using this framework not only considers the activities of players in each level but more importantly, the interactions between them, which take the form of decisions propagating downward and information propagating upward (Branford, 2011; Rasmussen and Svedung, 2000; Salmon et al., 2012).

Often “a quite normal variation in somebody's behavior” can release an accident (Rasmussen, 1997). Also, even if this particular variation is avoided, the accident would very likely be released by another factor in time. One important point of consideration in this regard is to see the actions of workers or the errors that triggered an accident in a broader socio-technical context since those actions are impacted by decisions and activities of other players in all the 6 stated levels of Fig. 1 (Rasmussen and Svedung, 2000; Svedung and Rasmussen, 2002).

The AcciMap methodology was developed by Professor Jens Rasmussen (1997) in conjunction with his 6-layer risk management framework, which was illustrated in Fig. 1. This methodology captures the associated socio-technical factors of an accident within an integrated framework and analyzes the contribution of those factors in causing the accident. This graphical representation is useful in structuring the analyses of hazardous work systems and in identifying the interactions between different levels of decision-makers, which shape the landscape in which accidents may “unfold” themselves (Svedung and Rasmussen, 2002).

It is noteworthy that AcciMap is part of a broader proactive risk management process to develop risk assessment strategies from generalizing the analysis of previous accidents (Branford, 2011). In general, analysis of past accidents within the stated framework can define patterns of hazards within an industrial sector. Such analysis can lead to the definition of preconditions for safe operations, which is a main focus of proactive risk management systems. However, as thoroughly discussed and analyzed by Underwood and Waterson (2014), AcciMap has certain inadequacies, which can be addressed by combining it with other analysis techniques.

This methodology has been used as an independent tool for accident analysis in different domains as well. These applications include chemical processing (CSB Report, 2014, 2015), transportation (Rasmussen and Svedung, 2000; Underwood and Waterson, 2014), aviation (Branford, 2011), public health (Vicente and Christoffersen, 2006), anti-terrorism (Jenkins et al., 2010; Waterson and Jenkins, 2011), gas production (Hopkins, 2000), and most recently, oil and gas drilling (Tabibzadeh and Meshkati, 2015).

In the context of maritime transportation, to our knowledge, the AcciMap methodology has been only applied by Rasmussen and Svedung (2000) to analyze the three accidents of Zeebrügge; capsizing of the roll on/roll off (RORO) Ferry Herald of Free Enterprise, capsizing and wrecking of the RORO Ship Vinca Gorthon in the North Sea, and grounding of gas tanker Balina in Lake Mälaren. This study can be safely considered as the first systemic investigation that also uses the powerful AcciMap framework to analyze a major recent maritime accident, the Sewol Ferry capsizing.

An AcciMap describes failures, decisions and actions at each of the six levels of Fig. 1 through the construction of a causal diagram. In addition, this methodology maps the interrelationships of those levels. In general, the AcciMap diagram is an integrated framework, which provides a big-picture to illustrate the context in which an accident occurred as well as the interactions between different levels of a socio-technical system that resulted in that event (Branford, 2011).

As stated in the introduction section, the AcciMap methodology